

circumstances is very great. We can read by the light of the moon and by that of the sun; yet the latter is 800,000 times as intense as the former.

698. Again, the eye adapts itself to different distances. If we look at a remote object through a telescope, we have to pull out the tube to a certain length, according to the distance, before we can see it to advantage. No such artificial adjustment is necessary with the eye. We look successively at objects 1, 5, 10, and 20 feet off; and in each case the eye instantly adapts itself to the distance, and we see without an effort.

699. An object may move with such velocity that we can not see it, as is the case with a cannon-ball. This is because the image formed on the retina does not remain sufficiently long to produce an impression. When an image is once formed, it remains from one-sixth to one-third of a second after the object has disappeared. Hence a burning stick whirled rapidly round seems to form a circle of fire, and a meteor or a flash of lightning, instead of appearing in a succession of luminous points, produces a continuous train of light in the heavens.

Optical Instruments.

700. Several of the more important optical instruments remain to be described. They are for the most part combinations of the different lenses and mirrors already mentioned.

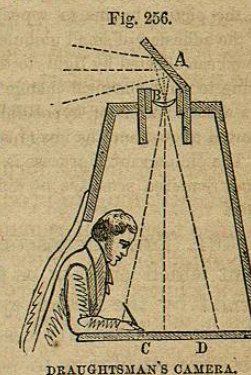
701. THE CAMERA OBSCURA.—We have seen that, when rays from an object brilliantly illuminated are admitted through an aperture into a dark room, an inverted image is formed. This image is apt to be indistinct. We may give it a sharper outline by placing a double convex lens in the aperture, and receiving the image on a white ground

one of the most remarkable properties of the eye? Give an example of the difference of intensity in the light admitted to the eye. 698. Show how the eye adapts itself to different distances. 699. Why is it that an object moving with very great velocity is not seen? When an image is once formed, how long does it remain after the object has disappeared? Give examples. 700. Of what are optical instruments for the most part combinations? 701. What is meant by the Camera Obscura? How

at its focus. Such an arrangement is called the Camera Obscura, or *dark chamber*.

For practical purposes, the camera obscura must be portable. A close box, painted black on the inside, is therefore substituted for the darkened room. This instrument enables the draughtsman to sketch material objects or natural scenery with great ease and accuracy, and is indispensable to the daguerreotypist and photographer.

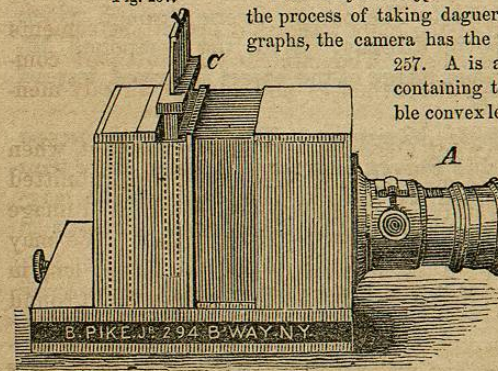
702. *Draughtsman's Camera*.—Fig. 256 represents the camera as used by draughtsmen. To be conveniently traced, the image must be thrown on a horizontal surface, and this is effected by making the opening in the top of the box and receiving the rays on a mirror, A, inclined at an angle of forty-five degrees. From this mirror they are reflected to a meniscus, B, which crosses the aperture, and are by it refracted to the horizontal surface, C D, where, on white paper placed to receive it, is formed a distinct image, which can be readily traced with a pencil. The upper part of the draughtsman's person is admitted through an opening in the side of the box, over which a dark curtain must be drawn, so as to exclude all light except what enters from above.



DRAUGHTSMAN'S CAMERA.

Fig. 257.

703. *Daguerreotypist's Camera*.—As used in the process of taking daguerreotypes and photographs, the camera has the form shown in Fig.



DAGUERREOTYPIST'S CAMERA.

257. A is a brass sliding tube, containing two achromatic double convex lenses, which is drawn out far enough to bring the focus at the right spot. The image is received on a piece of ground glass, fitted into a frame, which slides in a groove in the back of the camera. When a daguerre-

is the camera made portable? By whom is the camera used? 702. Describe the draughtsman's camera. 703. Describe the daguerreotypist's camera. How is the plate

otype is to be taken, the ground glass is withdrawn, and another frame, C, containing a prepared plate, carefully shielded from the light, is introduced in its place. A door in front of C is then raised, and the image formed by the lenses is thus allowed to fall on the plate.

The plate is of copper, covered on one side with a thin sheet of silver, which is rendered sensitive by exposure to the vapor of iodine. The rays transmitted through the camera, by that property inherent in them which we have called *actinism*, in a few seconds produce a chemical effect on the sensitive surface, and the plate is then removed to a dark room. No change is visible on its surface; but, as soon as it is exposed to the vapor of mercury, the picture begins to appear and soon becomes distinct. It is produced by the adhesion of small globules of mercury to those parts of the plate that have been affected by light, to the exclusion of the rest; and this adhesion is owing to some chemical change in the parts so affected. After being washed in a weak solution of hyposulphite of soda, and then in water, the plate is allowed to dry, and the image is fixed.

The photographic process is similar, except that the image is received on paper rendered sensitive by different preparations, instead of on a metallic plate.

704. **THE MICROSCOPE.**—The Microscope is an instrument which enables us to see objects too small to be discerned by the naked eye. This is the case with objects whose visual angle is less than $\frac{1}{360}$ of one degree; the microscope enables us to see them by increasing their visual angle.

Microscopes are divided into two classes, Single and Compound. A Single Microscope is one through which the object is viewed directly. With the Compound Microscope a magnified image of the object is viewed, instead of the object itself.

705. **The Single Microscope.**—The single microscope consists of a double convex lens (or sometimes more than one), through which we look at the object to be magnified. The principle on which it operates is shown in Fig. 258.

The arrow *bc* would be seen by the naked eye under the visual angle *bAc*. When the lens *m* is interposed, the rays are so refracted as to form

prepared? Give an account of the daguerreotype process. How does the photographic process differ from it? 704. What is the Microscope? How does it enable us to see minute objects? Name the classes into which microscopes are divided. What is a Single Microscope? What is a Compound Microscope? 705. Of what does the single microscope consist? With Fig. 258, explain the principle on which the

the visual angle *DAE*, and the arrow appears to be of the size *DE*, much larger than it really is. Sometimes an exceedingly minute object becomes visible when brought very near the eye, but in that position the rays enter the eye with such divergency that a confused image is produced. The microscope corrects this excessive divergency, and presents a clear and magnified image.

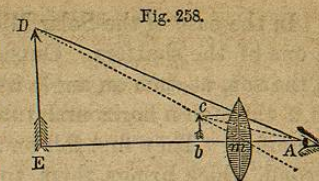


Fig. 258.

706. **The Compound Microscope.**—The compound microscope is a combination of two, three, or four convex lenses, through which we view a magnified image of an object instead of the object itself. The lenses are fixed in tubes moving one within the other, and suitable apparatus is provided for adjusting them, for holding the object under examination, and throwing on it a strong light. When but two lenses are employed, they are arranged as represented in Fig. 259.

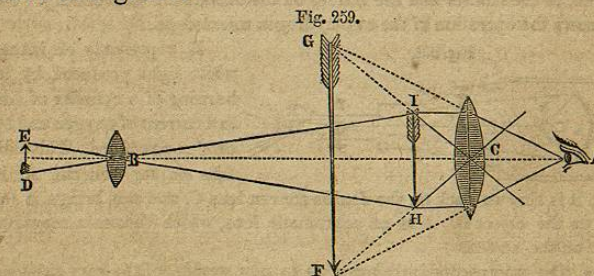


Fig. 259.

DE is the object, and *B*, the lens nearest to it, is called the *object-glass*. *C*, the lens nearest the eye, is called the *eye-glass*. A magnified image of the arrow is formed at *HI* by the lens *B*. This image is viewed through the lens *C*, and is thus still further magnified, being seen under an increased visual angle at *FG*. If the magnifying power of *B* is 20, and that of *C* 4, the image seen will be 80 times the size of life.

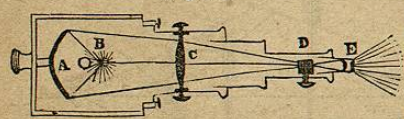
707. **Solar and Oxy-hydrogen Microscopes.**—These microscopes are used for throwing magnified images on a white screen in a darkened room.

single microscope operates. 706. Describe the compound microscope. With the aid of Fig. 259, name the parts and show the operation of the compound microscope. 707. For what are the Solar and the Oxy-hydrogen Microscope used? Describe the

In the case of the Solar Microscope, an aperture is made in one of the shutters. Outside of this a mirror is placed, in the sun, at such an angle as to reflect the rays that fall on it through a horizontal tube towards the object to be magnified. They first fall on a convex lens, and then on a second, which brings them to a focus on the object, and thus illuminates it brilliantly. Another lens, at the opposite extremity of the instrument, produces the magnifying effect. A screen, from ten to twenty feet off, receives the image, which increases in size with the distance. If the screen is too far removed, the image becomes faint; but so powerful is the light concentrated on the object that a very great magnifying effect may be produced without any lack of distinctness.

In the Oxy-hydrogen Microscope, the principle is the same, but the brilliant light produced by burning lime in a current of oxygen and hydrogen is substituted for the rays of the sun. Accordingly, with this instrument, the aperture in the shutter and the mirror on the outside are unnecessary. Fig. 260 shows the operation of the oxy-hydrogen microscope.

Fig. 260.



B represents an intense white light produced by the burning of a cylinder of lime in a current of oxygen and hydrogen combined. This light falls on the reflector A, by which it is thrown back on the double convex lens C, and this brings it to a focus on the object D. E is an achromatic lens, which throws a magnified image on the screen.

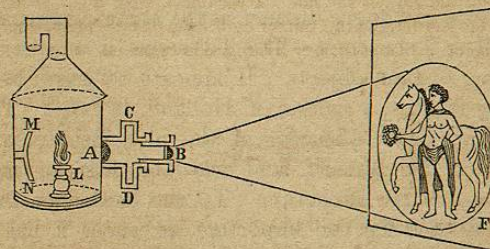
708. The microscope introduces us to new worlds, of the very existence of which we would otherwise have been ignorant. It reveals to us, in every drop of water in which vegetable matter has been infused, swarming myriads of moving creatures,—miniature eels, infinitesimal lobsters, ravenous monsters with distended jaws preying on their feeble fellows,—all endowed with the organs of life, and so minute that their little drop is to them a world nearly as large as ours to us. It shows us the feeding apparatus of the flea magnified to frightful dimensions, and his body arrayed in a panoply of shining and curiously jointed scales, studded at intervals with long spikes. The mould on decaying fruit it magnifies into bushes with branches and leaves,

solar microscope, and its operation. What is the effect of removing the screen to a greater distance from the instrument? What light is employed in the oxy-hydrogen microscope? With Fig. 260, show how this microscope operates. 709. What is said of the revelations of the microscope? What difference does it exhibit between the

displaying all the regularity and beauty of the vegetable creation. It discloses to us many striking facts connected with physiology and chemistry. It shows us the imperfection of the finest works of art, when compared with those of nature. The edge of the sharpest razor, viewed through a microscope, is full of notches; the point of a needle is blunt, and its surface is covered with inequalities. The magnified sting of a bee, on the other hand, is perfectly smooth, regular, and pointed. The finest thread of cotton, linen, or silk, is rough and jagged: whereas in the filament of a spider's web not the slightest irregularity can be detected.—In a word, the revelations of the microscope are in the highest degree wonderful and interesting; and, to whatever we direct it, we always find abundant matter to reward our labor and stimulate us to further researches.

709. THE MAGIC LANTERN.—The Magic Lantern is an instrument for throwing on a screen magnified images of transparent objects. It operates on the same principle as the oxy-hydrogen microscope, but for its illuminating power has an ordinary lamp instead of the intense light produced by burning lime.

Fig. 261.



THE MAGIC LANTERN.

Fig. 261 represents the magic lantern. L is the lamp. MN is the reflector, which throws the light on the lens A. This lens brings it to a focus on the picture, which is painted on a glass slider and introduced into the opening CD. The lens B receives the rays from the slider, and throws a magnified image on the screen F.

710. *Phantasmagoria*.—When a powerful light is used, and the tube containing the magnifying lens or lenses is capable of being drawn out or pushed in, so as to bring them at different distances from the object, we have what is called a Phantasmagoria Lantern.

works of art and those of nature? 709. What is the Magic Lantern? How does it differ from the oxy-hydrogen microscope? With Fig. 261, describe the magic lan-

To exhibit the Phantasmagoria, a transparent screen is suspended, on one side of which is the exhibitor with his lantern, on the other the spectators. Having brought the lantern close to the screen and drawn out the tube till the image (which will be quite small) is perfect, the exhibitor walks slowly back. He thus gradually increases the size of the image, while he preserves its distinctness by pushing in the tube as he recedes. The effect on the spectators is startling. The room being dark, they can not see the screen, but only the illuminated image, which, as it grows larger, appears to be moving towards them; even those who are familiar with the instrument can hardly disabuse their minds of this impression. When the exhibitor approaches the screen and pulls out the tube, the image becomes smaller and appears to recede.

711. *Dissolving Views*.—Dissolving Views, in which one picture appears to melt into another, are produced by two magic lanterns, inclined so as to throw their images on the same spot. An opaque shade is made to revolve in front of the instruments, in such a way as gradually to intercept the rays from one and uncover the tube of the other. The first picture fades, and a new one takes its place, becoming more and more distinct as the other disappears.

712. *THE TELESCOPE*.—The Telescope is an instrument for viewing distant objects. It appears to have been invented by Metius, a native of Holland, in 1608. The following year, Galileo, hearing of the new instrument, constructed one for himself, and was the first to make a practical use of the invention. To the Telescope, Astronomy is indebted for the important advances it has made during the last two centuries.

Telescopes are of two kinds, Refracting and Reflecting. In the former, which were the first constructed, lenses are used; in the latter, polished metallic mirrors.

713. *Refracting Telescopes*.—The simplest form of the telescope is that devised by Galileo. It is a tube containing a convex object-glass and a concave eye-glass. By the former parallel pencils are made to converge towards a focus, where they would form an inverted image; but be-

tern. 710. What is the Phantasmagoria Lantern? How are the phantasmagoria produced? What is said of their effect? 711. What are Dissolving Views? How are they produced? 712. What is the Telescope? By whom was it invented? Who first made a practical use of the invention? Name the two kinds of telescopes.

fore reaching the focus they fall on the concave lens, and have their convergency so far corrected that an object is distinctly seen by an eye at the extremity of the tube. The Opera-glass consists of two Galilean Telescopes combined. The night-glass used by sailors is on the same plan.

In the instrument called the Astronomical Telescope, both object-glass and eye-glass are convex. The former produces an inverted image at its focus; the latter, which is so placed that its focus falls at the same spot, refracts the rays diverging from this image, and thus renders it visible to the eye. The inversion of the image is of no consequence in observing the heavenly bodies; but, when objects on the earth are viewed, we want an erect image, and therefore in the Terrestrial Telescope two additional lenses are introduced to correct the inversion.

714. *Reflecting Telescopes*.—In Reflecting Telescopes, a speculum, or mirror, takes the place of the object-glass. These instruments appear in several different forms. The principle on which Herschel's is constructed, will be understood from Fig. 262.

The mirror SS is placed at the farthest extremity of the tube, inclined so as to make the rays that fall upon it converge towards the side of the tube in which

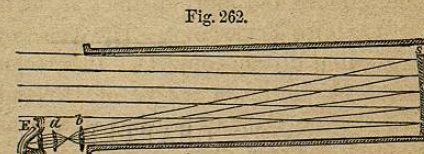


Fig. 262.

the eye-piece *ab* is fixed to receive them. The observer at E, with his back towards the heavenly body, looks through the eye-piece, and sees the reflected image. His position is such as not to prevent the rays from entering the open end of the tube. The advantage gained with this instrument depends in a great measure on the size of the mirror; for all the rays that fall on it are concentrated and transmitted to the eye.

715. The largest telescope ever constructed was made by the Earl of Rosse. The great mirror is six feet in diameter, and weighs four tons. The tube, at the bottom of which it is placed, is of wood hooped with iron. It is fifty-two feet long and seven feet across. It is computed that with this instrument 250,000 times as much light from a heavenly body is collected and transmitted to the eye as ordinarily reaches it.

713. Describe the Galilean Telescope. Of what does the Opera-glass consist? Describe the Astronomical Telescope. How does the Terrestrial Telescope differ from the Astronomical? 714. In reflecting telescopes, what takes the place of the object-glass? With Fig. 262, explain the principle on which Herschel's Telescope operates. On what does the advantage gained with this instrument depend? 715. Describe the telescope of the Earl of Rosse. How great is the advantage gained with it?

EXAMPLES FOR PRACTICE.

1. (*See* § 594.) How long does it take a ray from the moon to reach the earth, the moon's distance being 240,000 miles?
2. The planet Jupiter is 496,000,000 miles from the sun. How long does it take a ray of light from the sun to reach the planet?
3. A ray of light from the sun is about 12,326 seconds longer in reaching the newly discovered planet Neptune than in reaching Jupiter. About how many miles farther from the sun is Neptune than Jupiter?
4. (*See* § 595.) A holds his book 1 foot, and B holds his 3 feet, from a certain candle. How much more light does A receive than B?
5. The planet Uranus is twice as far from the sun as the planet Saturn. How does the light received at Saturn compare in intensity with that received at Uranus?
6. (*See* § 650.) How many times is the ordinary heat of the sun increased by a burning glass with an area of 10 square inches, the focus of which has an area of $\frac{1}{10}$ of a square inch?
7. A convex lens has a focus $\frac{1}{5}$ of a square inch in area, and increases the heat of ordinary sun-light 200 times; what is the area of the lens?

CHAPTER XV.

ACOUSTICS.

716. ACOUSTICS is the science that treats of sound.

717. NATURE AND ORIGIN OF SOUND.—Sound is an impression made on the organs of hearing by the vibrations of elastic bodies, transmitted through the air or some other medium. These vibrations may be compared to the minute waves which ripple the surface of a pond when a stone is thrown in,—spreading out from a centre, but growing smaller and smaller as they recede, till finally they are no longer perceptible. They are produced by percussion, or any shock which gives an impulse to the particles of the sounding body. There is no sound that can not be traced to mechanical action.

718. Bodies whose vibrations produce clear and regular

sounds are called Sonorous. Bell-metal, glass, the head of a drum, are sonorous.

719. That sound is produced by vibrations is proved in various ways. A person standing near a piano-forte or an organ, when it is played, feels a tremulous motion in the floor of the apartment, as well as in the instrument itself if he touches it. We perceive the same tremor in a bell when in the act of being rung. In like manner, if we strike a tumbler so as to produce a sound, and then touch the top, we feel an internal agitation; and, when the vibrations are stopped, as they are by contact with the finger, the sound ceases with them. If we put water in a glass and produce a sound by rubbing the top with the finger, the liquid is agitated, and its motion continues until the sound dies away.—Place some fine sand on a square piece of glass, and, holding it firmly with a pair of pincers, draw a violin-bow along the edge. The sand is put in motion, and finally settles on those parts of the glass that have the least vibratory movement.—If a tuning-fork be struck and applied to the surface of mercury, minute undulations may be observed in the metal.

That these vibrations are communicated to the air and by it transmitted to the ear, also admits of easy proof. The rapid passage of a heavy cart or stage shakes the walls of a house. The discharge of artillery sometimes breaks windows. These effects are due to the vibrations suddenly produced in the air. If there is no air or other medium to transmit the vibrations to the ear, no sound is heard. We have already seen (§ 439) that a bell rung in an exhausted receiver can hardly be heard; if the air could be entirely removed, it would be wholly inaudible. Sound, therefore, does not leap from point to point, but is transmitted by vibrations communicated from one particle to another.

720. All sonorous bodies are elastic, but all elastic bodies are not sonorous.

Soft bodies are generally non-elastic, and consequently not sonorous. This is the case with cotton, for example, which yields little or no sound when struck by a hammer. It is on this account that music loses much of its effect in rooms with tapestried walls or curtained windows. Hence, also, a speaker finds it more difficult to make himself heard in a crowded room than in one that is empty.

721. TRANSMISSION OF SOUND.—All the sounds that or-

716. What is Acoustics? 717. What is Sound? How are sound-waves produced? To what is every sound traceable? 718. What bodies are called Sonorous? Give examples. 719. How is it proved by familiar experiments that sound is produced by vibrations? If a tuning-fork be struck and applied to the surface of mercury, what may be observed? How is it proved that these vibrations are communicated to the air and by it transmitted to the ear? 720. What property belongs to all sonorous bodies? What bodies are, for the most part, not sonorous? Give examples. What follows from the fact that soft bodies are not sonorous? 721. By what are the sounds